

## WHAT IS CLAIMED IS:

1. An image display apparatus which comprises a display device that displays an image to be presented to a passenger on a vehicle on a front windshield  
5 portion of the vehicle, comprising:
  - vehicle measurement unit adapted to measure a position and azimuth of the vehicle on a world coordinate system;
  - head measurement unit adapted to measure a  
10 position of a head of the passenger on the vehicle on a coordinate system defined in the vehicle; and
  - control unit adapted to control the display device to display the image at a position according to the position and azimuth of the vehicle measured by  
15 said vehicle measurement unit, and the position of the head measured by said head measurement unit, on the front windshield portion.
2. The apparatus according to claim 1, wherein said  
20 vehicle measurement unit comprises external world image sensing unit adapted to sense an image of an external world of the vehicle.
3. The apparatus according to claim 2, wherein said  
25 vehicle measurement unit calculates positions of indices in the image, which are included in the image of the external world sensed by said external world

image sensing unit, and measures the position and azimuth of the vehicle on the world coordinate system on the basis of the calculated position.

5     4.     The apparatus according to claim 2, wherein said vehicle measurement unit further comprises rotational velocity measurement unit adapted to measure rotational velocities of right and left rear wheels of the vehicle, and

10             said vehicle measurement unit calculates positions of indices in the image, which are included in the image of the external world sensed by said external world image sensing unit, and measures the position and azimuth of the vehicle on the world  
15     coordinate system on the basis of the calculated positions, and the rotational velocities measured by said rotational velocity measurement unit.

5.     The apparatus according to claim 1, wherein said  
20     head measurement unit comprises head image sensing unit adapted to sense an image of the head of the passenger on the vehicle, and

           said head measurement unit calculates positions of indices in the image, which are included in the  
25     image of the head of the passenger sensed by said head image sensing unit, and measures the position of the head of the passenger on the vehicle on the coordinate

system defined in the vehicle on the basis of the  
calculated positions.

6. The apparatus according to claim 1, wherein the  
5 image is an image indicating navigation information.

7. The apparatus according to claim 1, wherein said  
vehicle measurement unit measures the position and  
azimuth of the vehicle using a nonholonomic constraint.  
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8. A measurement apparatus which is mounted on a  
vehicle and is used to measure a position and azimuth  
of the vehicle on a world coordinate system,  
comprising:

15 external world image sensing unit adapted to  
sense an image of an external world of the vehicle;  
position calculation unit adapted to calculate  
positions of indices in the image, which are included  
in the image of the external world sensed by said

20 external world image sensing unit; and

position/azimuth measurement unit adapted to  
measure the position and azimuth of the vehicle on the  
world coordinate system on the basis of the positions  
of the indices in the image calculated by said position  
25 calculation unit.

9. The apparatus according to claim 8, further comprising rotational velocity measurement unit adapted to measure rotational velocities of right and left rear wheels of the vehicle, and

5       said position/azimuth measurement unit measures the position and azimuth of the vehicle on the world coordinate system further using the rotational velocities measured by said rotational velocity measurement unit.

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10. A measurement apparatus which measures a position and orientation of an image sensing device or an object sensed by the image sensing device by detecting indices on an image of the object sensed by the image sensing

15       device, comprising:

          an index selection unit adapted to select indices which are to be observed on the sensed image without being occluded,

          wherein the position and orientation of the image  
20       sensing device or the object sensed by the image sensing device are measured on the basis of information of the selected indices.

11. The apparatus according to claim 10, wherein said  
25       index selection unit comprises:

          index information holding unit adapted to hold information associated with each index; and

occlusion determination unit adapted to determine  
a presence/absence of occlusion of each index on the  
basis of the information associated with each index  
held by said index information holding unit, and  
5        said index selection unit selects indices which  
are determined to be free from occlusion.

12.    The apparatus according to claim 11, wherein said  
index information holding unit holds at least  
10    position/orientation information of the image sensing  
device or the object upon sensing a template used to  
detect each index, and

      said occlusion determination unit determines the  
presence/absence of occlusion by comparing the  
15    position/orientation information of the image sensing  
device or the object held by said index information  
holding unit, and estimated values of a position and  
orientation of the image sensing device or the object.

20    13.    The apparatus according to claim 11, wherein said  
index information holding unit holds at least  
information associated with a direction of each index,  
and

      said occlusion determination unit determines the  
25    presence/absence of occlusion by comparing the  
information associated with a direction of each index  
held by said index information holding unit with an

estimated value of a direction of the image sensing device.

14. The apparatus according to claim 11, wherein said  
5 index information holding unit holds at least a position of each index, and

said occlusion determination unit determines the presence/absence of occlusion on the basis of the position of each index, estimated values of a position  
10 and orientation of the image sensing device, and shape information of a real space.

15. An image display method executed by an image display apparatus which comprises a display device that  
15 displays an image to be presented to a passenger on a vehicle on a front windshield portion of the vehicle, comprising:

a vehicle measurement step of measuring a position and azimuth of the vehicle on a world  
20 coordinate system;

a head measurement step of measuring a position of a head of the passenger on the vehicle on a coordinate system defined in the vehicle; and

a control step of controlling the display device  
25 to display the image at a position according to the position and azimuth of the vehicle measured in the vehicle measurement step, and the position of the head

measured in the head measurement step, on the front windshield portion.

16. A measurement method which is mounted on a  
5 vehicle and is used to measure a position and azimuth of the vehicle on a world coordinate system, comprising:

an external world image sensing step of sensing  
an image of an external world of the vehicle using an  
10 image sensing device;

a position calculation step of calculating  
positions of indices in the image, which are included  
in the image of the external world sensed in the  
external world image sensing step; and

15 a position/azimuth measurement step of measuring the position and azimuth of the vehicle on the world coordinate system on the basis of the positions of the indices in the image calculated in the position calculation step.

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17. A measurement method which measures a position and orientation of an image sensing device or an object sensed by the image sensing device by detecting indices on an image of the object sensed by the image sensing  
25 device, comprising:

an index selection step of selecting indices  
which are to be observed on the sensed image without  
being occluded,

wherein the position and orientation of the image  
5 sensing device or the object sensed by the image  
sensing device are measured on the basis of information  
of the selected indices.

18. The method according to claim 17, wherein the  
10 index selection step comprises:

an index information holding step of holding  
information associated with each index in a memory; and

an occlusion determination step of determining a  
presence/absence of occlusion of each index on the  
15 basis of the information associated with each index  
held by the memory, and

the index selection step includes a step of  
selecting indices which are determined to be free from  
occlusion.

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19. The method according to claim 18, wherein the  
memory holds at least information associated with a  
direction of each index, and

the occlusion determination step includes a step  
25 of determining the presence/absence of occlusion by  
comparing the information associated with a direction



of each index held by the memory with an estimated value of a direction of the image sensing device.

20. A program for making a computer function as an  
5 image display apparatus of claim 1.

21. A program for making a computer function as a measurement apparatus of claim 8.

10 22. A program for making a computer execute an image display method of claim 15.

23. A program for making a computer execute a measurement method of claim 16.

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24. A computer readable storage medium storing a program of claim 20.

25. An information processing method which comprises  
20 a detection step of detecting a position of an index in a sensed image sensed by image sensing unit adapted to sense an image of a real space where the index is laid out, and a first calculation step of calculating a coordinate position of the index upon projecting the  
25 index in the real space onto the sensed image on the basis of the position of the index in the real space and a position and orientation of the image sensing

unit when at least one of the position of the index in the real space and the position and orientation of the image sensing unit is obtained based on a measurement, and executes a process for determining correspondence

5 between indices at coordinate positions with a smaller distance on the basis of coordinate positions of indices detected in the detection step and the coordinate position calculated in the first calculation step on the sensed image, comprising:

10 a second calculation step of calculating a value using a normal vector to an index of interest, and a visual axis vector of the image sensing unit; and

a determination step of determining, on the basis of a range of the value calculated in the second

15 calculation step, whether or not the process for calculating the coordinate position of the index of interest on the sensed image in the first calculation step is to be executed,

wherein when it is determined in the

20 determination step that the process for calculating the coordinate position of the index of interest on the sensed image in the first calculation step is to be executed, the process for determining correspondence between indices at coordinate positions with a smaller

25 distance is executed based on the coordinate position of the index of interest calculated in the first

calculation step and the coordinate positions of the indices detected in the detection step.

26. The method according to claim 25, wherein the  
5 second calculation step includes a step of calculating an angle the normal vector of the index of interest makes with the visual axis vector of the image sensing unit or a value based on the angle.

10 27. The method according to claim 26, wherein the determination step includes a step of determining that the process for calculating the coordinate position of the index of interest on the sensed image in the first calculation step is to be executed when the angle is  
15  $90^\circ + \alpha$  ( $\alpha \geq 0$ ).

28. The method according to claim 25, further comprising:

a correction step of correcting the position and  
20 orientation of the image sensing unit using a distance between the coordinate position calculated in the first calculation step and the coordinate position detected in the detection step of the determined corresponding indices;

25 a virtual space image generation step of generating an image of a virtual space using the

position and orientation corrected in the correction step; and

a composition step of compositing and outputting the image of the virtual space generated in the virtual space image generation step and the sensed image sensed by the image sensing unit.

29. An information processing apparatus which comprises image sensing unit adapted to sense an image of a real space where an index is laid out, detection unit adapted to detect a position of the index in a sensed image sensed by the image sensing unit, and first calculation unit adapted to, when at least one of a position of an index in the real space and a position and orientation of the image sensing unit is obtained based on a measurement, calculating a coordinate position of the index upon projecting the index in the real space onto the sensed image on the basis of the position of the index in the real space and the position and orientation of the image sensing unit, and executes a process for determining correspondence between indices at coordinate positions with a smaller distance on the basis of coordinate positions of indices detected by the detection unit and the coordinate position calculated by the first calculation unit, on the sensed image, comprising:

second calculation unit adapted to calculate a value using a normal vector to an index of interest, and a visual axis vector of the image sensing unit; and

determination unit adapted to determine, on the  
5 basis of a range of the value calculated by said second calculation unit, whether or not the process for calculating the coordinate position of the index of interest on the sensed image by the first calculation unit is to be executed,

10 wherein when said determination unit determines that the process for calculating the coordinate position of the index of interest on the sensed image by the first calculation unit is to be executed, the process for determining correspondence between indices  
15 at coordinate positions with a smaller distance is executed based on the coordinate position of the index of interest calculated by the first calculation unit and the coordinate positions of the indices detected by the detection unit.

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30. A program for making a computer execute an information processing method of claim 25.

31. A computer readable storage medium storing a  
25 program of claim 30.

32. An identification method of an index used to measure a position and orientation of an image sensing device for sensing an image of a real space, comprising:

5           a position/orientation measuring step of measuring roughly a position and orientation of the image sensing device;

          an image sensing step of sensing an image of a real space including an index using the image sensing  
10 device;

          a first image coordinate calculation step of calculating coordinate of the index, which is included in the image of the real space obtained in the image sensing step, in the obtained image; and

15           a second image coordinate calculation step of calculating a position of the index in a sensed image sensed by the image sensing device, whose position and orientation are obtained in the position/orientation measuring step,

20           wherein the index is identified on the basis of the coordinate of the index calculated in the first image coordinate calculation step, the coordinate of the index calculated in the second image coordinate calculation step, and relationship between a visual  
25 axis vector of the image sensing device obtained in the position/orientation measuring step and a normal vector of the index.

33. An identification method of an index used to measure a position and orientation of an object in a real space, comprising:

5           a position/orientation measuring step of measuring roughly a position and orientation of the object;

          an image sensing step of sensing an image of the object using an image sensing device, which is fixed in  
10   position;

          a first image coordinate calculation step of calculating coordinate of an index, which is included in the image of the object obtained in the image sensing step, in the obtained image; and

15           a second image coordinate calculation step of calculating a position of the index in a sensed image sensed by the image sensing device, on the basis of position and orientation are obtained in the position/orientation measuring step,

20           wherein the index is identified on the basis of the coordinate of the index calculated in the first image coordinate calculation step, the coordinate of the index calculated in the second image coordinate calculation step, and relationship between a visual  
25   axis vector of the image sensing device obtained in the position/orientation measuring step and a normal vector of the index.

34. An identification method of an index used to measure a position and orientation of an object in a real space, comprising:

5           a first position/orientation measuring step of measuring roughly a position and orientation of the object;

          a second position/orientation measuring step of measuring roughly a position and orientation of an  
10 image sensing device which senses the object;

          an image sensing step of sensing an image of the object using the image sensing device;

          a first image coordinate calculation step of calculating coordinate of an index, which is included  
15 in the image of the object obtained in the image sensing step, in the obtained image; and

          a second image coordinate calculation step of calculating a position of the index in a sensed image sensed by the image sensing device, on the basis of a  
20 position and orientation of the object with reference to the image sensing device, or of the image sensing device with reference to the object, which is obtained in the first and second position/orientation measuring step,

25           wherein the index is identified on the basis of the coordinate of the index calculated in the first image coordinate calculation step, the coordinate of



the index calculated in the second image coordinate calculation step, and relationship between a visual axis vector of the image sensing device obtained in the second position/orientation measuring step, and a  
5 normal vector of the index obtained in the first position/orientation measuring step.